#116

DATE ISSUED AUG 2 1984

27

ORNL-6062/P2

ornl

OAK RIDGE NATIONAL LABORATORY

MARTIN MARIETTA

Report on the Oak Ridge Sewage Sludge Land-Farming Experience

Part II - Pathways Analysis

T. W. Oakes 36
W. F. Ohnesorge 36
K. L. Daniels 36
H. M. Braunstein 36
J. T. Kitchings 42
W. A. Alexander 36

MANAGED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

Printed in the United States of America. Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road, Springfield, Virginia 22161
NTIS price codes—Printed Copy: A03; Microfiche A01

ORNL-6062/P2
Distribution
Category UC-41

REPORT ON THE OAK RIDGE SEWAGE SLUDGE LAND-FARMING EXPERIENCE

Part II - Pathways Analysis

T. W. Oakes
W. F. Ohnesorge
K. L. Daniels
H. M. Braunstein
J. T. Kitchings
W. A. Alexander

Department of Environmental Management
Environmental and Occupational Safety Division

Manuscript Completed - April 17, 1984
Date Published - August 1984

Prepared by the
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831
operated by
Martin Marietta Energy Systems, Inc.
for the
U.S. Department of Energy
Contract No. DE-AC05-84OR21400

Executive Summary

In 1978 negotiations were initiated between the city of Oak Ridge and the Department of Energy (DOE) Oak Ridge Operations Office to consider the land disposal of treated sludge from a new city sewage treatment plant, which was scheduled for completion in 1983. The sludge was to be placed on several parcels of land (~ 1500 acres) located within the DOE Oak Ridge Reservation for a trial period of five years. The sludge was to be used as a nitrogen and phosphorus nutrient supplement for tree planting operations on poor quality forest sites within the Reservation. The initial sludge disposal site consisted of 65 acres located on the southeast side of Chestnut Ridge, bordered on the south by the old Bethel Valley Road and on the west by Mount Vernon Road. Deposition on this site was begun in November 1983.

On March 22, 1984, it was learned that some of the deposited sludge had been contaminated with various radionuclides primarily Co-60 and Cs-137. A radiation survey had been performed above the City's sewage main on Emory Valley Road. The readings were as high as 45 μR/hr (5 times background) midway between the L&N railroad line and Lafayette Drive. Disposal of sludge on the 65-acre site was temporarily halted on March 25, 1984 and a comprehensive sampling and monitoring study which was described in Part I of this report was instituted on March 30, 1984.

Subsequent to the data assessment, calculations were made to delineate the potential dose received from exposure to five different environmental pathways: a) direct radiation from the field; b) inhalation of dust emissions from the sludge disposal area; c) ingestion of water resulting from radionuclides being leached from the soil and transported via surface runoff into Melton Hill Lake; d) ingestion of fish caught in Melton Hill Lake; and e) ingestion of deer meat from animals which might graze on the contaminated site.

The inhalation pathway did not seem to be a critical one. The results were based on an assumption of an average mass in air of 35 micrograms per meter cubed. If maximum measured values of particulate

mass in air for the DOE/ORO reservation had been assumed, the dose commitment from the inhalation pathway would still have been negligible.

The water consumption pathway contains a number of significant uncertainties. A erosion rate of 3% per year was assumed to be conservative for a grass covered field, but there is a large uncertainty in this number. Published KD values were used and contain large uncertainties. A dilution factor of 3 by runoff from other fields draining into the receiving bay was used and is felt to be conservative but somewhat uncertain. The dose commitment assumes that the only water consumed is by a swimmer who consumes a total of 25 mL per day for 120 days for a total of 3 liters. This assumption is probably conservative. The water consumption pathway appears to be the second highest contributor to the total dose commitment to the maximally exposed individual.

Most of the uncertainties of the water consumption pathway also apply to the fish consumption pathway. The published water to fish concentration factors are thought to be conservative but generally have a high degree of uncertainty associated with them. The dose commitments are based on eating one kilogram of fish. For the purpose of obtaining an overall estimate, it was assumed that 10 kilograms of fish were consumed by the maximally exposed individual. Of all the exposure routes, the fish consumption pathway appears to be the most significant one.

The deer consumption pathway contains a number of uncertainties such as the published soil to grass transfer coefficients and the soil to meat coefficients. The contribution to deer meat due to the deer drinking runoff was not calculated but the results of an estimate indicated that this contribution would be less than 1/5 of the grass to deer contribution. The dose commitment due to eating deer meat was calculated on a per kilogram basis. For the total assessment of dose, it was assumed that the maximally exposed individual would consume 10 kilograms of deer meat. The dose commitment from this pathway is very small.

Results of analyses from these five pathways are shown below. The total annual exposure was calculated to be 4.2 mrem to the endostial cells (critical organ) and 1.1 mrem to the total body. Most of the total dose commitment was due to the fish consumption with a secondary contribution due to the consumption of water through swimming. The nuclides contributing the most to the dose to the critical organ and the total body were Sr-90 and Cs-137.

Summary of Dose Contributions by Pathway[a]
to the Maximally Exposed Member of the Public

Pathway	Dose Commitment (mrem/yr) Endostial Cells	Total Body
Direct Radiation	b	b
Direct Inhalation	1.98E-3	5.53E-4
Water Ingestion	2.78E-2	3.67E-3
Fish Ingestion	4.14	1.05
Deer Meat Ingestion	8.65E-3	2.10E-3
Total	4.2	1.1

[a] All dose commitments have background subtracted.

[b] Measured values indicated background levels on the old Bethel Valley Road.

Table of Contents

List of Tables

Abstract

The data presented in Part I of the "Report on the Oak Ridge Sewage Sludge Land-farming Experience" was used to analyze the potential hazard to humans from the transport of radioactive material from the sludge disposal area into the surrounding environment. A number of environmental pathways were examined to determine the possible radiation dose that humans might incur if radionuclides from the disposal site were concentrated in an environmental medium other than soil.

Subsequent to the data assessment, calculations were made to delineate the potential dose received from exposure to five different environmental pathways: a) direct radiation from the field; b) inhalation of dust emissions from the sludge disposal area; c) ingestion of water resulting from radionuclides being leached from the soil and transported via surface runoff into Melton Hill Lake; d) ingestion of fish caught in Melton Hill Lake; and e) ingestion of deer meat from animals which might graze on the contaminated site. Results of analyses from these four pathways showed the total annual exposure to be 4.2 mrem to the endostial cells (critical organ) and 1.1 mrem to the total body.

Pathways Analysis

The pathway analysis included direct radiation from the sludge contaminated field, inhalation of dust from the field, consumption of water by a swimmer swimming in Clark Center swimming area, consumption of fish caught from the McCoy embayment and consumption of deer that might graze on the disposal field. The concentrations of the radionuclides used in calculating doses are listed in Table 1. The dose conversion factors used in determining the radiation exposure are shown in Table 2. This preliminary analysis is intended to give a conservative assessment of the most critical pathways.

1. Direct Radiation

This pathway is the simplest to assess since direct radiation surveys have been conducted on the field itself and the roadway adjacent to the field. The most likely exposure to a member of the public, is that to a runner running along the old Bethel Valley Road which lies adjacent to the sludge field. Even though the roadway is only 3 to 4 meters distance from the field at certain points, the radiation level on this road is indistinguishable from background.

2. Inhalation of Dust from Field

Dust loading of the air in this sludge disposal area was assumed to be similar to the loading indicated by past measurements on the DOE/ORO reservation. The airborne dust particles were assumed to be entirely from the contaminated soil and to contain the same specific activity as the top 3 inches of soil. This exposure path appears to be a minor one as indicated in Table 3. The maximum annual dose is to the lung and is only 0.005 mrem.

3. Water Consumption

The runoff from the sludge contaminated field was assumed to all go into the McCoy embayment, south of Bethel Valley Road, and subsequently into the main body of Melton Hill Lake which includes the

Table 1. Radionuclide Concentrations used for caluclating dose received by a human from various pathway exposures.

Radio-nuclide	Mean Conc in field (pCi/g)	Mean Background Conc (pCi/g)	Net Conc Field* (pCi/g)
Co-60	2.96	0	2.96
Cs-137	1.72	1.1	.62
Sr-90	.6	.15	.45
U-234	1.12	.55	.57
U-235	.09	.065	.025
U-238	.47	.45	.02
Pu-238	8E-03	9E-04	7.1E-03
Pu-239	.039	.014	.025

* Concentrations used in all dose calculations.

Table 2. Dose conversion factors used for calculating dose commitment due to inhalation (A) and ingestion (B). Each factor relates the dose received (mrem) as a result of inhaling or ingesting 1 μCi of material.

A. Inhalation

Organ	Co-60	Cs-137	Sr-90	U-234	U-235	U-238	Pu-238	Pu-239
LUNG	1.30E+03	1.62E+01	8.50E+03	5.36E+05	5.36E+05	4.80E+05	6.08E+05	5.80E+05
LLI WALL	2.85E+01	1.60E+01	8.90E+02	1.10E+02	1.10E+02	2.80E+02	1.20E+02	1.10E+02
T BODY	8.20E+03	3.26E+01	1.50E+02	1.60E+04	1.60E+04	1.50E+04	6.00E+04	6.70E+04
KIDNEYS	5.85E+01	5.13E+01	3.65E+00	1.70E+03	1.70E+03	1.50E+03	9.00E+04	1.03E+05
LIVER	1.20E+02	5.23E+01	1.90E+01	1.62E+01	1.62E+01	1.76E+01	7.00E+05	7.97E+05
OVARIES	1.85E+01	5.00E+01	3.65E+00	1.61E+01	1.62E+01	1.47E+01	3.50E+04	4.00E+04
R MAR	6.45E+01	4.91E+01	1.20E+02	2.40E+02	1.90E+02	2.00E+02	2.61E+05	3.03E+06
ENDOST	5.08E+01	5.31E+01	2.30E+02	2.50E+03	2.90E+03	2.90E+03	3.27E+06	4.16E+06
TESTES	6.12E+00	4.44E+01	3.65E+00	1.61E+01	1.41E+01	1.44E+01	3.50E+04	4.00E+04
THYROID	6.01E+01	4.47E+01	3.65E+00	1.61E+01	2.07E+01	1.59E+01	5.10E+03	5.80E+03
WT SUM	2.41E+02	4.83E+01	1.45E+03	1.11E+05	9.97E+04	9.86E+04	3.07E+05	3.47E+05

B. Ingestion

Organ	Co-60	Cs-137	Sr-90	U-234	U-235	U-238	Pu-238	Pu-239
LUNG	8.62E+00	1.00E+02	5.99E+00	6.87E+01	6.45E+01	6.13E+01	3.23E+00	3.63E+00
LLI WALL	4.02E+01	2.59E+01	7.78E+01	1.50E+02	1.60E+02	1.40E+02	2.10E+02	2.00E+02
T BODY	4.37E+00	4.91E+01	9.45E+01	2.30E+03	2.10E+03	2.00E+03	2.83E+01	3.13E+01
KIDNEYS	5.67E+00	7.73E+01	5.99E+00	6.70E+03	6.00E+03	6.00E+03	5.72E+01	6.33E+01
LIVER	6.83E+00	7.87E+01	5.71E+00	6.32E+01	5.49E+01	5.35E+01	4.40E+02	4.90E+02
OVARIES	1.24E+01	7.54E+01	5.99E+00	6.32E+01	5.56E+01	5.34E+01	2.21E+01	2.48E+01
R MAR	5.42E+00	7.38E+01	4.30E+02	9.30E+02	7.20E+02	7.60E+02	1.70E+02	1.90E+02
ENDOST	3.99E+00	7.99E+01	8.60E+02	1.40E+04	1.20E+04	1.10E+04	2.10E+03	2.60E+03
TESTES	3.82E+00	6.68E+01	5.99E+00	6.32E+01	5.49E+01	5.38E+01	2.21E+01	2.48E+01
THYROID	3.10E+00	6.72E+01	5.99E+00	6.32E+01	5.79E+01	5.63E+01	3.23E+00	3.63E+00
WT SUM	1.13E+01	8.19E+01	8.75E+01	9.86E+02	8.49E+02	8.41E+02	1.37E+02	1.57E+02

Table 3. Maximum Individual Dose - Inhalation Pathway

Assumptions: The same assumptions were used for all the radionuclides except the solubility criteria.

1. An average air dust loading of 35 $\mu g/m^3$ is made up entirely of particulate from the field containing the radionuclide concentrations listed in Table 1.
2. The maxmially exposed individual is a jogger who runs on Old Bethel Valley Road past the field for one hour per day for one year, breathing at a rate of 20 liters per minute.
3. The uranium and plutonium radionuclides are insoluble (ICRP γ solubility). This is a "worst case" assumption.

Radionuclide	Max. Dose (mrem)	Critical[a] Organ	Total Body Dose (mrem)
Co-60	5.85E-5	Lung	3.69E-4
Cs-137	5.04E-7	Endost[b]	3.10E-7
Sr-90	1.52E-5	Endost	1.66E-6
U-234	4.66E-3	Lung	1.39E-4
U-235	2.04E-4	Lung	6.08E-6
U-238	1.49E-4	Lung	4.65E-6
Pu-238	3.60E-4	Endost	6.60E-6
Pu-239	1.58E-3	Endost	2.55E-5

[a] Critical organ was selected on the basis of the magnitude of the exposure - is usually an order of magnitude higher than results for all other organs.

[b] Endost = Endostial (bone surface cells).

Summary of Total Organ Dose Commitment from all Radionuclides

Organ	Dose Commitment in mrem per year
Lung	5.36E-03
LLI Wall	2.67E-06
Total Body	5.53E-04
Kidneys	6.82E-05
Liver	2.06E-05
Ovaries	1.19E-03
Red Marrrow	1.19E-03
Endostial	1.98E-03
Testes	2.00E-05
Thyroid	6.15E-06

swimming area in Clark Center Park. For the analysis, the radionuclides were assumed to have been transferred into runoff by both leaching of radionuclides and soil erosion (Table 4; assumption 3). There is no drinking water intake in the immediate vicinity of the disposal area. However, people do swim in the Clark Center Park area beyond the area where McCoy embayment empties into the lake. It was assumed in our dose calculations that a person would swim in the Park area every day for 120 days (May-September) and unintentionally ingest an average of 25 mL of water per day while swimming. The water in McCoy embayment which receives the runoff was assumed to be diluted by a factor of 3 by surface runoff from uncontaminated areas adjacent to the sludge field. No further dilution was assumed in the swimming area. The results of this pathway assessment are shown in Table 4. The intake of Sr-90 accounts for most of the exposure hazard with the highest dose of 0.028 mrem/yr occurring to the endostial cells.

4. Fish Consumption

Fish were assumed to have accumulated radionuclides from the same waters as those in which swimming takes place and to be removed from the water by individual sportfishermen. Specific activities of radionuclides in the fish were estimated using published concentration factors.[2,3] The results are shown in Table 5 and are given on a per kilogram consumed basis. Cs-137 accounted for the majority of the dose with the lung and endostial tissue being the critical organs. Published annual consumption rates[2,3] of fish vary from 4.4 to 21 kilograms per year so that the annual dose would be a function of the amount of fish consumed. For the assessment summary of the maximum dose commitment due to all pathways, a value of 10 kilograms of fish consumed was used.

5. Deer Consumption

Published transfer factors[4] for soil to vegetation and vegetation to meat were used to estimate the amount activity in deer meat (Table 6). It was assumed that the deer would eat 20 kg of grass per day. The results are shown in Table 6 with the resulting exposure

Table 4. Maximum Individual Dose - Water Ingestion Pathway

Assumptions: The same assumptions were used for all the radionuclides except the solubility criteria.

1. Only runoff water from the field will contain activity.
2. Runoff will contain both dissolved and particulate radionuclides.
3. Values used to estimate leaching of radionuclides from soil to water are Co-60 100; Cs-137 1000; Sr-90 20; U-234 1000; U-235 1000; U-238 1000; Pu-238 5000; Pu-239 5000.
4. Sheet erosion was assumed at a rate of 3% per year (grassy slopes).
5. Runoff water will not be used as drinking water and will drain to the embayment at Clark Center Park.
6. Runoff water will only be ingested unintentially by swimmers at a rate of 25 mL/day for 120 days.

Radionuclide	Max. Dose (mrem)	Critical[a] Organ	Total Body Dose (mrem)
Co-60	1.41E-3	LLI Wall[b]	1.54E-4
Cs-137	2.00E-4	Lung	9.83E-5
Sr-90	2.01E-2	Endost[c]	2.21E-3
U-234	5.68E-3	Endost	9.41E-4
U-235	8.43E-4	Endost	1.48E-4
U-238	6.54E-4	Endost	1.19E-4
Pu-238	1.70E-5	Endost	2.29E-7
Pu-239	1.55E-4	Endost	1.86E-6

[a] Critical organ was selected on the basis of the magnitude of the exposure - is usually an order of magnitude higher than results for all other organs.

[b] LLI wall = Lower Large Intestine Wall

[c] Endost = Endostial (bone surface cells).

Summary of Total Organ Dose Commitment from all Radionuclides

Organ	Dose Commitment in mrem per year
Lung	6.79E-04
LLI Wall	3.59E-03
Total Body	3.67E-03
Kidneys	4.03E-03
Liver	5.96E-04
Ovaries	7.61E-04
Red Marrow	1.09E-02
Endostial	2.78E-02
Testes	4.42E-04
Thyroid	4.17E-04

Table 5. Maximum Individual Dose - Fish Ingestion Pathway

Assumptions: The same assumptions were used for all the radionuclides except the solubility criteria.

1. Runoff water is diluted by a factor of 3 due to addition of water from two other streams that drain to the embayment, both free of radionuclides.
2. Fish live in this water and are caught by local sport fishermen.
3. Only fish flesh is ingested and at a rate between 4.4 and 21 Kg per year.
4. Uptake of radionuclides by fish is governed by the following concentration factors (activity in fish/activity in water): Co-60 50; Cs-137 2000; Sr-90 30; U-234 10; U-235 10; U-238 10; Pu-238 350; Pu-239 350.

Radionuclide	Max. Dose (mrem)	Critical[a] Organ	Total Body Dose (mrem)
Co-60	2.39E-3	LLI Wall[b]	2.60E-3
Cs-137	1.35E-1	Lung	6.64E-2
Sr-90	2.02E-1	Endost[c]	2.22E-2
U-234	7.57E-2	Endost	1.24E-2
U-235	2.92E-3	Endost	5.11E-4
U-238	2.08E-3	Endost	3.78E-4
Pu-238	2.27E-3	Endost	3.06E-5
Pu-239	1.82E-2	Endost	2.19E-4

a Critical organ was selected on the basis of the magnitude of the exposure - is usually an order of magnitude higher than results for all other organs.

b LLI wall = Lower Large Intestine Wall

c Endost = Endostial (bone surface cells).

Summary of Total Organ Dose Commitment from all Radionuclides

Organ	Dose Commitment in mrem per kg ingested
Lung	1.42E-01
LLI Wall	7.97E-02
Total Body	1.05E-01
Kidneys	1.49E-01
Liver	1.16E-01
Ovaries	1.11E-01
Red Marrow	2.11E-01
Endostial	4.14E-01
Testes	9.45E-02
Thyroid	9.45E-02

Table 6. Maximum Individual Dose - Deer Meat Ingestion Pathway

Assumptions: The same assumptions were used for all the radionuclides except the solubility criteria.

1. Radionuclides are uptaken from the soil to grass and grass to deer meat according to the following distribution coefficients:

Radionuclides	Soil-to-Grass Coefficient	Grass-to-Meat Coefficient
Co-60	9.4E-3	1.7E-2
Cs-137	1.1E-2	1.4E-4
Sr-90	2.9E-1	3.0E-4
U-234	2.9E-4	1.6E-6
U-235	2.9E-4	1.6E-6
U-238	2.9E-4	1.6E-6
Pu-238	2.2E-4	4.1E-4
Pu-239	2.2E-4	4.1E-4

2. Deer consume 20 Kg of vegetation per day.

Radionuclide	Max. Dose (mrem)	Critical[a] Organ	Total Body Dose (mrem)
Co-60	3.80E-4	LLI Wall[b]	4.13E-5
Cs-137	1.92E-4	Lung	9.42E-5
Sr-90	6.74E-4	Endost[c]	7.41E-5
U-234	7.57E-8	Endost	1.24E-8
U-235	2.79E-9	Endost	4.88E-10
U-238	2.05E-9	Endost	3.73E-10
Pu-238	2.67E-11	Endost	3.59E-13
Pu-239	1.19E-10	Endost	1.44E-12

a Critical organ was selected on the basis of the magnitude of the exposure - is usually an order of magnitude higher than results for all other organs.

b LLI wall = Lower Large Intestine Wall

c Endost = Endostial (bone surface cells).

Summary of Total Organ Dose Commitment from all Radionuclides

Organ	Dose Commitment in mrem per Kg meat ingested
Lung	2.78E-04
LLI Wall	4.91E-04
Total Body	2.10E-04
Kidneys	2.07E-04
Liver	2.20E-04
Ovaries	2.67E-04
Red Marrow	5.30E-04
Endostial	8.65E-04
Testes	1.69E-04
Thyroid	1.63E-04

doses less than 0.001 mrem. For the purpose of this assessment, a value of 10 kilograms consumed by the maximally exposed individual was used for the assessment summary.

Assessment Summary

Results of summing all the major pathway exposures are shown in Table 7. The total annual exposure was 4.2 mrem to the endostial cells (critial organ) and 1.1 mrem to the total body.

As previously stated, the direct ratiation pathway assessment was the most straight forward since the radiation levels were relatively simple to measure and compare with background. The inhalation pathway did not seem to be a critical one. The results were based on an assumption of an average mass in air of 35 micrograms per meter cubed. If maximum measured values of particulate mass in air for the DOE/ORO reservation had been assumed, the dose commitment from the inhalation pathway would still have been negligible.

The water consumption pathway contains a number of significant uncertainties. An erosion rate of 3% per year was assumed to be conservative for a grass covered field, but there is a large uncertainty in this number. Published KD values[4] (Table 4; assumption 3) were used and contain large uncertainties. A dilution factor of 3 by runoff from other fields draining into the receiving bay was used and is felt to be conservative but somewhat uncertain. The dose commitment shown in Table 4 and in the summary table (Table 7) assumes that the only water consumed is by a swimmer who consumes a total of 25 mL per day for 120 days for a total of 3 liters. This assumption is probably conservative. The water consumption pathway appears to be the second highest contributor to the total dose commitment to the maximally exposed individual.

Most of the uncertainties of the water consumption pathway also apply to the fish consumption pathway. The published water to fish concentration factors are thought to be conservative but generally have a high degree of uncertainty associated with them. The dose

Table 7

Summary of Dose Contributions by Pathway[a]
to the Maximally Exposed Member of the Public

Pathway	Dose Commitment (mrem/yr) Endostial Cells	Total Body
Direct Radiation	b	b
Direct Inhalation	1.98E-3	5.53E-4
Water Ingestion	2.78E-2	3.67E-3
Fish Ingestion	4.14	1.05
Deer Meat Ingestion	8.65E-3	2.10E-3
Total	4.2	1.1

[a] All dose commitments have background subtracted.

[b] Measured values indicated background levels on the old Bethel Valley Road.

commitments shown in Table 5 are based on eating one kilogram of fish. For the purpose of obtaining an overall estimate, it was assumed that 10 kilograms of fish were consumed by the maximally exposed individual and this value is shown in Table 7. Of all the exposure routes, the fish consumption pathway appears to be the most significant one. The deer consumption pathway contains a number of uncertainties such as the published soil to grass transfer coefficients and the soil to meat coefficients. The contribution to deer meat due to the deer drinking runoff was not calculated but the results of an estimate indicated that this contribution would be less than 1/5 of the grass to deer contribution. The dose commitment due to eating deer meat was calculated on a per kilogram basis and is shown in Table 6. For the total assessment of dose, it was assumed that the maximally exposed individual would consume 10 kilograms of deer meat. As shown in Table 7, the dose commitment from this pathway is very small.

Most of the total dose commitment was due to the fish consumption with a secondary contribution due to the consumption of water through swimming. The nuclides contributing the most to the dose to the critical organ and the total body were Sr-90 and Cs-137.

References

1. Department of Environmental Management. Report on the Oak Ridge Sewage Sludge Land-farming Experience, Part 1 - Data Presentation, ORNL-6062, Oak Ridge National Laboratory, Oak Ridge, TN, 1984.

2. U.S. Nuclear Regulatory Commission, Regulatory Guide 1.109, Calculation of Annual doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR 50, Appendix I, USNRC, Washington, D. C., 1977.

3. W. Miller, et al, Recommendations Concerning Models and Parameters Best Suited to Breeder Reactor Environmental Radiological Assessments, ORNL-5529, Oak Ridge National Laboratory, Oak Ridge, TN, 1980.

4. Baes III, C. F., "Prediction of Radionuclide K_D values from Soil-Plant Concentration Ratios," Trans. Am. Nucl. Soc., 41:53-54, 1982.

5. U.S. Department of Energy. DOE Order 5480.1 Chapter XI, 1981.

ORNL-6062/P2
Dist. Cat. UC-41

Internal Distribution

1. H. H. Abee
2. E. Aebischer
3-7. W. A. Alexander
8. D. M. Bradburn
9-13. H. M. Braunstein
14. T. R. Butz
15. W. Chance
16. K. E. Cowser
17-21. K. L. Daniels
22. N. W. Durfee
23. J. S. Eldridge
24. W. F. Furth
25. H. B. Gerstner
26. F. J. Homan
27. C. C. Hopkins
28. C. G. Jones
29. R. G. Jordan
30. B. A. Kelly
31-35. J. T. Kitchings
36. J. M. Loar
37. W. E. Manrod
38. L. J. Mezga
39. J. B. Murphy
40-44. T. W. Oakes
45-49. W. F. Ohnesorge
50. P. D. Parr
51. D. C. Parzyck
52. C. H. Petrich
53. P. M. Pritz
54. C. R. Richmond
55. E. R. Rothschild
56. M. Sanders
57. L. H. Stinton
58. L. E. Stratton
59. J. H. Swanks
60. L. D. Voorhees
61. J. C. White
62. Central Research Library, ORNL
63-64. Laboratory Records Department
65. Laboratory Records, ORNL-RC
66. ORNL Y-12 Technical Library
67. ORNL Patent Office

External Distribution

68-297. Given distribution as shown in TID-4500 under Health and Safety category.
298. B. J. Davis, Environmental Protection Branch, U.S. Department of Energy, Oak Ridge Operations Office, Oak Ridge, TN 37831.
299. V. Fayne, Environmental Protection Branch, U.S. Department of Energy, Oak Ridge Operations Office, Oak Ridge, TN 37831.
300. Clayton Gist, Oak Ridge Associated Universities, Oak Ridge, TN 37831.
301. W. Hibbitts, Environmental Protection Branch, U.S. Department of Energy, Oak Ridge Operations Office, Oak Ridge, TN 37831.
302. J. A. Lenhard, U.S. Department of Energy, Oak Ridge Operations Office, Oak Ridge, TN 37831.
303. W. Range, U.S. Department of Energy, Oak Ridge Operations Office, Oak Ridge, TN 37831.